# Self–Regulation of Pollution: The Role of Market Structure and Consumer Information

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## 1. Introduction

The purpose of this paper is to provide an analytical framework to assess the efficiency, distributional, and environmental consequences of voluntary codes in pollution–generating industries. In particular, we identify the conditions under which voluntary regimes are likely to be a viable alternative to mandatory regimes. Attention focusses upon the complex interaction among market structure, demand, and environmental factors including imperfect competition among pollution–generating firms and imperfect consumer knowledge of environmental consequences of production.

Voluntary codes are a form of *self–regulation*. Any regulatory regime — whether it be voluntary or mandatory — consists of a target and institutional arrangements which provide incentives to attain the target. Institutional arrangements include a rule (for example, a voluntary or mandatory code for emissions) and an *ex–post* governance structure (monitoring and sanctioning activities) which ensure compliance with the rule. A key difference between voluntary and mandatory regimes is that the choices of target and institutional arrangements are private rather than public decisions. In particular, since the choice of rule is a private decision, the rule is not backed up by the force of law and hence compliance with the rule is voluntary rather than mandatory. Voluntary codes can be chosen at either the firm or industry level.[1]

Four potential sources of market failure are present in our analysis of voluntary compliance regimes: (i) imperfect competition, (ii) pollution byproducts, (iii) imperfect consumer information regarding the environmental impact of production, and (iv) pollution abatement is a public good. These sources of market failure interact and determine firm and industry incentives to adopt voluntary codes.

In an oligopolistic market structure with pollution–generating firms, the first two sources of market failure work in conflicting directions. The oligopoly itself tends to restrict output relative to the socially efficient (and perfectly competitive) level. In contrast, the presence of an unpriced pollution externality leads to overproduction and hence excessive environmental damage relative to the social optimum. Whether the imperfect competition effect or the externality effect dominates will depend upon the degree of concentration in the industry, technology and demand conditions, the type of pollutant being emitted and the current assimilative capacity of the environment (the degree of environmental damage). For instance, the imperfect competition effect will tend to dominate the externality effect in a highly concentrated industry which emits pollutants which tend to break down fairly quickly while the opposite will hold in a less concentrated industry which emits persistent pollutants.

In the absence of legal sanctions, the primary source of compliance incentives in voluntary regimes is consumers. Consumers can effectively sanction firms by reducing demand for pollution–generating products. Clearly, the ability of consumers to sanction firms depends critically on the quality of the information they possess regarding (or attitudes toward) industrial environmental performance. Poorly informed consumers possess weak sanctioning power and, hence, compliance incentives are diminished.

Finally, the public good nature of pollution abatement efforts leads to an underprovision of abatement technology; firms cannot be excluded from benefitting from competitors' abatement efforts since consumer demand depends upon industry environmental performance. Consequently, a free–rider problem in abatement effort emerges. The free–rider problem is particularly pronounced when consumers are well–informed and can lead to a significant gap in the performance of firm versus industry codes; an industry association is better placed to resolve free–rider problems since it makes decisions in the industry interest.

Simulation results are presented for two broad categories of pollutants — cumulative and noncumulative pollutants.[2] The identity of winners and losers in voluntary compliance regimes is highly dependent upon the respective levels of consumer sanctioning power and market power: for instance, in the case of cumulative pollutants, we find that voluntary regimes perform best when consumer sanctioning power and market power are strong.

The paper is organized as follows. An overview of alternative solutions to the externality problem is presented in Section 2. In Section 3, a graphical analysis of voluntary compliance is presented. An algebraic example is derived in Section 4. A simulation welfare analysis is presented in Section 5. Concluding remarks are presented in Section 6.

## 2. Alternative Solutions to the Externality Problem

The idea of fully privatizing or delegating traditional regulatory tasks to a polluting industry may initially seem to be a perversion of economic logic. It is certainly a radical departure from conventional economic thought on solutions to the externality problem. During the last 75 years, two broad schools of thought — Pigovian and Coasian — have dominated the economic analysis of externalities and hence policy–making.[3] While Pigovians and Coasians agree that externalities are caused by market failure and that correction requires government intervention, they disagree on the scope and degree of public intervention which is required. Neither school of thought suggests full delegation or decentralization as a viable solution.

Pigovians believe that the source of market failure is the missing market for pollution, that is, environmental assets are not priced. A Pigovian prescription for government intervention entails centralized choice of targets and institutional arrangements; for example, command–and–control regimes based on performance or design standards and incentive–based regimes based on taxes or marketable permits are both centralized solutions to the externality problem — they are centralized solutions because targets, rules, and ex–post governance structures are chosen by central authorities even though individual emission decisions may be decentralized under incentive–based regimes. The regulatory agency, acting in the public interest, acquires and processes information about the costs and benefits of pollution control and chooses a set of institutional arrangements which maximizes social welfare. Pigovian solutions implicitly define a set of property rights for polluters.[4] Incentive–based rules are based on a *polluter pays principle*, forcing polluters to internalize external costs imposed on others as a result of their polluting activities.

In contrast, Coasians maintain that the source of market failure is ill–defined property rights. They argue that if property–rights are well–defined over environmental assets, then decentralized bargaining between polluters and victims will lead to a Pareto–improving and self–enforcing agreement consisting of a mutually acceptable level of pollution and compensatory payment. Moreover, if transaction costs are zero, then the self–enforcing agreement will attain the social optimum. A Coasian prescription for government intervention is restricted to the definition of property rights. While the initial assignment of property rights does not have allocative consequences — even if property rights are not assigned efficiently, decentralized bargaining will lead to an efficient allocation of property rights — it does have distributional consequences. For instance, if a polluter has the right to pollute, then correction of the externality requires that the victim pays the polluter to restrict emissions; in contrast, if the victim has the right to a pollution–free environment, then the polluter must compensate victims for any pollution generated. Thus, unlike incentive–based Pigovian rules which require that a polluter always pays for the right to pollute, the identity of who pays under decentralized bargaining is determined by the initial assignment of property rights.[5]

In theory, Pigovian and Coasian solutions can both sustain competitive equilibria characterized by externalities as Pareto optimum under well–specified conditions. Again, although there are no efficiency consequences of choosing one solution over the other, there will be distributional consequences.

In practice, the implementation of Pigovian and Coasian solutions in Western economies has met with limited success. As predicted by innumerable non–Coasians, Coasian solutions are not well–suited to many environmental problems. Many environmental assets are either public goods or common property resources for which property rights cannot be defined. In addition, many environmental problems involve large numbers of polluters and victims, leading to substantive coordination problems, free–riding and high transaction costs. Finally, imperfect information regarding the opponent's bargaining curve can result in missed Pareto–improving bargains.[6] In short, decentralized bargaining cannot resolve the externality problem because of multiple sources of market failure.

Centralized Pigovian solutions have also failed to solve the externality problem because of multiple sources of regulatory failure. Regulators have imperfect knowledge about the costs and benefits of pollution abatement which result in errors in the target and rule–setting process and, consequently, welfare losses. Regulatory capture by interest groups such as environmental groups or industry itself also leads to suboptimal outcomes. In addition, limited regulatory resources for monitoring and enforcement leads to underprovision of compliance incentives and hence incomplete enforcement of environmental laws.

Neither decentralized bargaining nor mandatory compliance regimes have been effective choices for managing the environment. In addition, mandatory compliance regimes, particularly the prevalent command–and–control regime, have proven to be prohibitively expensive. It is not surprising that debt–ridden governments are searching for more cost–effective solutions to the externality problem. The key question which this paper addresses is whether or not voluntary compliance regimes can provide sufficient incentives for the correction of externalities in a cost–effective manner.

The success or failure of voluntary and mandatory regimes is, in large part, determined by the strength of compliance incentives provided by the regime. In traditional Pigovian analysis, incentives to comply with mandatory codes are provided in the form of expected financial penalties for noncompliance with the law. The source of compliance incentives is the government — the regulatory agency and statutory law.[7] In contrast, incentives to comply with voluntary codes are primarily provided by consumers of the pollution–generating product and, in the case of industry codes, the industry association.

Our analysis departs from traditional Pigovian analysis by explicitly recognizing the role that consumers play in the environmental protection process. In the absence of an agency acting in the public interest, consumers can both acquire and process information regarding the environmental consequences of industrial activities as well as exercise a powerful sanctioning role in the marketplace through reduced demand or consumer boycotts. Depending upon preferences, quality of information, and budget constraints, consumers will, to some extent, internalize the externality in their consumption decisions; in this sense, the role of consumers in a voluntary compliance regime may play a similar role to pollution victims in a Coasian bargaining situation. The key difference between the role of consumers in a voluntary compliance regime and victims in a Coasian bargaining situation is that the behaviour of agents in a voluntary compliance regime is mediated by prices.

## 3. A Graphical Analysis

### 3.1. Environmental Preferences and Consumer Demand

Consumers can play a pivotal role in the provision of incentives for firms to voluntarily reduce emissions in the absence of regulatory directives. A growing empirical literature in environmental benefit measurement identifies a positive willingness to pay on the part of consumers for improvements in environmental quality.[8] A positive willingness to pay for environmental improvements is a monetary indicator that consumers hold preferences over different states of the environment. As a result, consumer demand depends, in part, on the environmental consequences of production. Let us suppose, for the sake of argument, that consumers' willingness to pay for a pollution–generating good, $Q$, is given by the following relationship:

$$P(Q, Z) = f(Q) - MD(Z) \tag{3.1}$$

where $Z$ is the industry level of pollution emitted during the production process and $MD(Z)$ is the monetized value of the environmental damage caused by an additional unit of pollution — in other words, the marginal damage curve. If consumers do not care about the environmental consequences of production, then willingness to pay for a good depends solely upon the quantity consumed, $f(Q)$; $P = f(Q)$ is a standard inverse demand curve so that willingness to pay is decreasing in the level of consumption, $Q$, due to diminishing marginal benefits of consumption. When consumers care about environmental consequences of production, then their willingness to pay for a product is also decreasing in the level of pollution which the industry generates. More formally, willingness to pay is strictly decreasing in industrial pollution levels when the environmental damage function $D(Z)$ is strictly convex in $Z$ — $P_Z = -D_{ZZ}(Z) < 0$ since $D_{ZZ}(Z) > 0$. Most pollutants are characterized by convex environmental damage functions as damages generally increase at an increasing rate as pollution levels rise. Thus, consumer demand will be dampened in pollution–intensive industries and enhanced in environmentally friendly industries.

### 3.2. Impact of Industrial Pollution Abatement on Consumer Demand

Firms can, to some extent, control their pollution emission levels. In particular, several options for reducing pollution may be available to firms; firms' may be able to reduce pollution emissions by reducing output, shifting their product mix toward low pollution–intensive goods, changing their production process or by installing pollution abatement equipment which lowers the level of waste residuals created per unit of output. Let us suppose, for simplicity, that a firm is restricted to two options for reducing pollution emissions: a firm can reduce output and/or install an emission control input. For instance, a public utility could reduce sulphur dioxide emissions by reducing electricity generation and/or by installing scrubbers in their tall stacks or switching to low sulphur coal. The total level of emission control input used by the industry is denoted by $E$. Pollution is thus generated by a process involving output and emission control inputs — $Z = Z(Q, E)$ — where pollution levels are increasing in the level of industry output and declining in the industry's level of emission control input usage.

Firm level choices of output and emission control input usage directly affect the level of pollution and, hence, consumer demand. To see this, let $f(Q) = A - Q$ and $MD(Z) = Z$ so that consumer demand is given by $P(Q, Z) = A - Q - Z$, where $A > 0$. Suppose further that the pollution production function (and, for this example, the marginal damage function) is described by $Z = Q - \gamma E$, where $\gamma < 1$ parameterizes the efficiency level of the emission control input. The pollution production function assumes that a unit of production increases pollution by one unit while installation of a unit of emission control input reduces pollution by less than one unit $\gamma$. As the abatement technology becomes more efficient, $\gamma$ increases and a higher proportion of a unit of pollution can be reduced. Substituting $Z = Q - \gamma E$ into $P(Q, Z)$ yields $P(Q, E) = A + \gamma E - 2Q$. We can now see that consumer demand or willingness to pay, $P(Q, E)$ is a function of $Q$ and $E$; willingness to pay for a good is decreasing in the level of output and increasing in the industry's usage of abatement technology.

— **INSERT FIGURE 1 HERE** —

Figure 1 illustrates consumer demand, $P(Q; E = 0)$, when the industry does not install any emission control inputs. Note that $P(Q; E = 0)$ is simply the difference between $f(Q)$ and $MD(Q; E = 0)$ — consumers' willingness to pay for a pollution–generating good is net of the value of any environmental damage costs generated during the production process. In other words, consumers internalize the value of environmental damage costs in their consumption decisions. Pollution emissions cause the demand curve to pivot inward towards the origin, resulting in a steeper demand curve, and a lower willingness to pay for any given level of production; the total reduction in consumers' willingness to pay for $Q$ is given by the area $ABC$.

— **INSERT FIGURE 2 HERE** —

By installing emission control inputs, the industry can reduce the level of emissions per unit of output, hence the level of environmental damage for any given level of output. The marginal damage curve for a fixed level of industry emission control input usage, $\overline{E}$, is labelled $MD(Q; \overline{E})$ in Figure 2. The installation of $\overline{E}$ shifts the marginal damage curve $MD(Q; E = 0)$ down and to the right to $MD(Q; \overline{E})$; the downward shift is equal to $\gamma\overline{E}$ — the amount of waste residuals removed and the environmental damage prevented by the emission control inputs. Notice that when production is below $Q(\overline{E})$, no environmental damage is incurred when $\overline{E}$ units of emission control inputs are installed. Environmental damage is increasing for levels of production in excess of $Q(\overline{E})$. As the industry's level of emission control input usage is increased, $Q(\overline{E})$ is increasing and the marginal damage curve shifts to the right. Thus, the industry effectively chooses the location of the marginal damage curve through its choice of $E$. Substituting the marginal damage curve $MD(Q;\overline{E})$ into the inverse demand curve given by equation 3.1 yields the following kinked demand curve:

$$P(Q;\overline{E}) = \begin{cases} A + \gamma\overline{E} - 2Q & \text{if } Q \geq Q(\overline{E}) \\ A - Q & \text{otherwise} \end{cases} \tag{3.2}$$

$P(Q;\overline{E})$ is illustrated in Figure 2. Note that the $\gamma\overline{E}$ downward shift in the marginal damage curve leads to an $\gamma\overline{E}$ upward shift in the demand curve for levels of production in excess of $Q(\overline{E})$. Further, by installing $\overline{E}$, the industry can lower the reduction in consumers' willingness to pay by the area $ADFC$. Thus, industry output and emission control input usage affect consumer demand in two ways. First, pollution emissions cause environmental damages which reduce consumers' willingness to pay for a good (inward pivoting of the demand curve). Second, firm investment in pollution abatement technology can reduce the level of emissions per unit of output and hence environmental damages, thereby offsetting the reduction in consumers' willingness to pay (outward shift of the demand curve).

### 3.3. Impact of Pollutant Type and Consumer Knowledge on Consumer Demand

Two additional factors affect the shape and location of the consumer demand curve: the type of pollutant emitted as a byproduct of production and the extent of consumer knowledge about the environmental consequences of production.

Pollutants can be grouped into two broad categories — cumulative and noncumulative pollutants. Cumulative pollutants accumulate in the environment as the environment has no assimilative capacity to break them down. Examples of cumulative pollutants include inorganic chemicals, minerals, plastics and radioactive waste. In contrast, the environment has some natural assimilative capacity to break down noncumulative pollutants. Provided that the absorptive capacity of the environmental medium is high enough relative to the emission rate, noncumulative pollutants may not accumulate in the environment at all. For instance, degradable wastes such as organic residuals are attacked and broken down by bacteria in a body of water while the atmosphere has some capacity to absorb carbon dioxide emissions. If the assimilative capacity of the environment is exceeded, noncumulative pollutants can become cumulative. In order to distinguish between cumulative and noncumulative pollutants, we parameterize the marginal damage curve as $MD(Z) = \delta Z$, where $\delta > 0$. Cumulative pollutants are characterized by high values of $\delta$ while noncumulative pollutants causing gradual, steady environmental degradation are characterized by low values of $\delta$.

Consumer knowledge about the true environmental consequences of production also plays a major factor in the determination of demand for pollution–generating products. Consumer knowledge about environmental consequences is captured by the parameter $\theta \in [0, 1]$ in the inverse demand curve $P(Q, Z) = f(Q) - \theta MD(Z)$. In words, willingness to pay for a pollution–generating good depends upon how well–informed consumers are about the true marginal damage curve.[9] For instance, consumers of paper products are relatively well–informed (high $\theta$) about clear–cutting practices in the British Columbia lumber industry and the consequent environmental impacts due largely to the public education efforts of Greenpeace. In contrast, consumers were relatively poorly–informed (low $\theta$) about the environmental impact of unlined oil sumps used in Alberta during the oil boom in the 1980s.

Taking into account the type of pollutant and the extent of consumer knowledge about the environmental consequences of the pollutant, we can rewrite consumer demand given by equation 3.2 as follows:

$$P(Q; \overline{E}, \theta, \delta) = \begin{cases} A + \theta\delta\gamma\overline{E} - (1 + \theta\delta)Q & \text{if } Q \geq Q(\overline{E}) \\ A - Q & \text{otherwise} \end{cases} \tag{3.3}$$

Referring again to Figure 2, if consumers are well–informed about the environmental consequences of highly toxic emissions (high $\theta$ and $\delta$), then the inward pivoting (measured by $\theta\delta$) and the outward shift (measured by $\theta\delta\gamma\overline{E}$) in the demand curve will be large. If consumers are poorly–informed about the environmental impact of relatively benign emissions (low $\theta$ and $\delta$), then the impact of environmental preferences on consumer demand will be small.

In the following two subsections, we present a graphical analysis of the social optimum, monopoly and perfect competition outcome to provide an intuitive feel for the model of voluntary codes. Algebraic examples of the alternative regimes are presented in the next section, followed by a simulation analysis.

### 3.4. Socially Optimal Pollution Control

The social optimum is a useful benchmark for evaluating industry choices of output and emission control input levels and the resulting level of environmental quality in voluntary regimes. A benevolent, perfectly informed social planner will choose industry levels of output and emission control inputs to maximize social welfare, where social welfare is the sum of gross surplus less producer and environmental damage costs.

Social welfare maximization requires choosing an activity level so as to equate the social marginal benefit of the activity with the social marginal cost. The social marginal benefit of installing emission control inputs, $MB_E^* = -D_Z Z_e$, is equal to the reduction in environmental damages which can be obtained by installing an additional unit of emission control input. Referring to Figure 3, notice that the social marginal benefit of emission control inputs is downward–sloping, reflecting diminishing marginal returns from the installation of emission control inputs; diminishing marginal returns arise because the marginal benefit accruing from emission reductions is falling. The social marginal cost of installing emission control inputs, $MC_E$, is simply the marginal cost of installation; $MC_E$ is assumed to be upward–sloping, reflecting increasing marginal costs of abatement. The socially optimal level of emission control input usage, $E^*$, is found at the intersection point of $MB_E^*$ and $MC_E$. Note that $E^*$ is independent of $\theta$.

— **INSERT FIGURE 3 HERE** —

The socially optimal output choice, given installation of $E^*$, is illustrated in Figure 4. As noted earlier, the choice of $E$ determines the location of the marginal damage curve. Installation of $E^*$ shifts the marginal damage curve southeast to $MD^*$. When consumers fully internalize the externality ($\theta = 1$), the demand curve is given by $P(Q, E^*)$ which is simply the difference between $f(Q)$ and $MD^*$; $P(Q, E^*)$ measures the net social marginal benefit of output, that is, the marginal benefit of consumption net of environmental consequences. The socially optimal level of output, $Q^*$, is found at the intersection point of $P(Q, E^*)$ and $MC_Q$, where $MC_Q$ measures the marginal cost of producing $Q$. The socially optimal price of $Q$ when consumers fully internalize the externality is denoted by $P^*\,(\theta = 1)$. If consumers do not internalize the externality ($\theta = 0$), then the demand curve is given by $f(Q)$. The socially optimal level of output is now the intersection point of $f(Q)$ and $MC^*$, where $MC^*$ is the social marginal cost incurred with the production of $Q$; $MC^*$ is the vertical summation of $MD^*$ and $MC_Q$.

— **INSERT FIGURE 4 HERE** —

Notice that while there are no allocative consequences associated with the value of $\theta$ — $Q^*$ is independent of $\theta$ — the price of $Q$ does vary with $\theta$. When consumers do not internalize the externality in their consumption decisions, then the socially optimal price of $Q$ is $P^*\,(\theta = 0)$; clearly, $P^*\,(\theta = 0) > P^*\,(\theta = 1)$. The socially optimal price of $Q$ is monotonically decreasing in $\theta$. It can also be seen in Figure 4 that consumer surplus is increasing in $\theta$, that is, consumers are better off the more informed they are about the environmental consequences of production.

### 3.5. Industrial Incentives to Adopt Voluntary Codes

What incentive do firms have to voluntarily install emission control inputs? Suppose that there is a single producer of the product who has the power to set prices. A profit–maximizing monopolist will choose a level of emission control input usage by equating the private marginal benefit of an additional unit of input to the marginal cost of installation. The marginal benefit to the monopolist of installing the input, $MB_E^M$, is the incremental revenue earned; $MB_E^M = P_E Q$, where $P_E = \theta\delta\gamma$ is the value of the reduction in the marginal damage when an additional unit of the emission control input is installed. Alternatively, $P_E$ is the increment which consumers are willing to pay for a unit of a more environmentally friendly good. Referring to Figure 2, each additional unit of emission control input installed results in an outward shift in the demand curve of $\theta\delta\gamma$. Thus, the incentive for a monopolist to install abatement technology is a pecuniary one — the monopolist can increase profits by exploiting consumers' environmental preferences to raise consumers' willingness to pay. It is important to emphasize that the monopolist's decision to install abatement technology is a purely *voluntary decision*. The decision is motivated by self–interest and does not require government intervention in any form, including mandated technology–based standards wherein regulations require the installation of a particular kind or level of emission control input.

The monopolist's privately optimal choice of emission control input is illustrated in Figure 3. Note that, in contrast to $MB_E^*$, $MB_E^M$ is upward–sloping. The monopolist's profit–maximizing choice of $E$ is found at the intersection point of $MB_E^M$ and $MC_E$ and is denoted by $E^M$. It can be shown that $MB_E^M$ will always cut $MC_E$ below $MB_E^*$, hence a monopolist will install too low a level of emission control inputs relative to the social optimum — $E^M < E^*$.

— **INSERT FIGURE 5 HERE** —

Underprovision of abatement technology results in a higher level of environmental damages for any given level of output. The marginal damage curve associated with $E^M$ is labelled $MD^M$ in Figure 5. Note that $MD^M$ lies everywhere above and to the left of $MD^*$.

When $\theta = 1$, market demand for the monopolist's output $Q$ is given by

$P(Q, E^M)$. The monopoly output level is the level of output which equates the private marginal benefit of output, $MR(Q, E^M)$, with the marginal production cost, $MC_Q$. It is easy to see in Figure 5 that the monopolist restricts output below the socially optimal level — $Q^M(\theta = 1) < Q^*$. In addition, the monopoly price, $P^M(\theta = 1)$, is higher than the socially optimal price, $P^*$.

The divergence between $Q^*$ and $Q^M$ is decreasing in $\theta$. In words, as consumers become better informed about the environmental consequences of production, a monopolist will adopt more environmentally friendly production processes, raising consumers willingness to pay for its product and hence enhancing the monopolist's incentive to produce output. As $\theta$ decreases, consumers willingness to pay for the product is less responsive to the monopolist's choice of abatement technology, reducing both the incentive to adopt more environmentally friendly production processes and to expand output. For instance, when $\theta = 0$, any pecuniary advantage of installing emission control inputs is removed as demand is no longer responsive to environmental performance. Consequently, $MB_E^M = 0$ and hence $E^M = 0$. Referring to Figure 5, demand is now given by $P(Q, E^M = 0)$. The monopolist's optimal output choice is restricted further to $Q^M(\theta = 0)$. Notice, however, that the monopoly price which emerges when $\theta = 0$, labelled $P^M(\theta = 0)$, is lower than $P^M(\theta = 1)$. When $0 < \theta < 1$, $Q^M$ and $P^M$ will lie in the respective intervals $\left[Q^M(\theta = 0), Q^M(\theta = 1)\right]$ and $\left[P^M(\theta = 0), P^M(\theta = 1)\right]$.

The monopolist's ability to mark–up prices derives directly from its market power. Figure 5 illustrates a paradox — a monopolist's market power is increasing in consumer knowledge about the environmental consequences of production. To see this, observe that the monopolist's market power or ability to mark–up prices is directly related to the price elasticity of the demand curve, $\epsilon$:

$$\frac{P - MC_Q}{P} = \frac{1}{|\epsilon|} \tag{3.4}$$

where $0 < |\epsilon| \leq 1$. As the price elasticity of demand declines, demand becomes less responsive to price changes and the monopolist's ability to mark–up prices increases. The price elasticity of demand is strictly decreasing in $\theta$, hence, market power is strictly increasing in $\theta$. Intuitively, as consumers become better informed about environmental consequences, the demand curve becomes steeper and hence demand is less responsive to price changes.

The price elasticity of demand (market power) is also decreasing (increasing) in $\delta$, the slope parameter of the marginal damage curve. Hence, the monopolist's market power will be increasing as the hazardousness of the pollution emissions is increasing; for instance, market power will be stronger when the pollutant is a cumulative as opposed to a noncumulative pollutant.

An important implication of the positive relationships between market power and $\theta$ and $\delta$ is that voluntary codes can potentially have strong anti–competitive effects. The anti–competitive effects of voluntary codes will be strongest when the industry is concentrated, consumers are well–informed and the pollutant in question is particularly damaging to the environment.

The extent to which consumers' environmental preferences affect firm choice of emission control input usage also depends upon the level of competition in the industry. As competition in the industry increases, individual firm's market power is declining and, as a result, incentives to install emission control inputs are diminished. In a perfectly competitive industry, for instance, firms are sufficiently small that individual decisions will not affect market prices. When firms are price–takers, there is no incentive to voluntarily install emission control inputs since firms cannot capture the pecuniary benefit. In other words, the marginal benefit to a perfectly competitive firm of installing abatement technology is zero and, given positive costs of installation, profit maximization requires that no technology be installed. The perfectly competitive output equilibria $Q^C(\theta = 0)$ and $Q^C(\theta = 1)$ are shown in Figure 5. When $0 < \theta < 1$, the competitive outcome will lie somewhere between these two solutions.

## 4. An Algebraic Example

For simplicity, we adopt a linear–quadratic model of homogeneous firms.[10] The number of firms, $n$, is fixed, hence there is no entry or exit into the industry. Each firm produces a pollution–generating good $q$, where $Q = nq$ is industry output. Individual producers may choose to install an emission control input $e$ to reduce emission levels $z$, where $z = q - \gamma e$; industrial emission control usage and pollution emissions are given by $E = ne$ and $Z = nz$, respectively. An individual producer's cost of production and abatement is assumed to be $C(q, e) = bq + \frac{k}{2}e^2$, where $b, k > 0$. Pollution generated by the industry causes environmental damage $D(Z) = \frac{\delta}{2}Z^2$, where $\delta > 0$. Consumer inverse demand is given by equation 3.3. Finally, in order to satisfy the *Second Law of Thermodynamics*, we make the following parameter assumption:[11]

$$\gamma < \sqrt{\frac{k}{\theta\delta}} \tag{4.1}$$

### 4.1. Social Optimum

We assume that the social planner has full information about the environmental consequences of production. The social planner will choose levels of $q$ and $e$ to maximize social welfare $SW(Q, E; n)$, where social welfare is the sum of gross surplus, $U(Q, E) = \int_0^Q f(t)dt - \theta D(Z(Q, E))$, less environmental damage costs not internalized by consumers, $(1-\theta) D(Z(Q, E))$, and industry production and abatement costs, $C(Q, E)$:

$$\max_{q,e} SW(Q, E; n) = \int_0^Q f(t)dt - D(Z(Q, E)) - C(Q, E)$$

Note that social welfare is independent of $\theta$ since the social planner takes into account the full environmental consequences of production. The social planner's decision rules for output and emission control input are characterized by the following pair of equations:

$$q^* : f(Q) - D_Z Z_q - C_q = 0 \tag{4.2}$$

$$e^* : -D_Z Z_e - C_e = 0 \tag{4.3}$$

Substituting the assumed functional forms and after some algebraic manipulation, we can derive the *Pareto* optimal decision rules as:

$$q^* = \left(k + n\delta\gamma^2\right) F \tag{4.4}$$

$$e^* = n\delta\gamma F \tag{4.5}$$

$$z^* = kF \tag{4.6}$$

where

$$F = \frac{A - b}{n\left[k(1+\delta) + n\delta\gamma^2\right]} \tag{4.7}$$

Again, note that the *Pareto* optimal decision rules do not depend upon $\theta$. Further, the environmental damage parameter $\delta$ is negatively correlated with output and pollution and positively correlated with the level of emission control input. Firm (industry) level quantities are strictly decreasing (increasing) in $n$.

### 4.2. Uncoordinated Industry Equilibrium: Company Codes

Following convention, we adopt the standard assumption that firms behave as Cournot–Nash competitors, that is, each producer chooses output and emission control input levels to maximize own profits, $\pi_i$, taking as given that the other producers are also choosing their best actions:

$$\max_{q_i, e_i} \pi_i(q_1, ..., q_n, e_1, ..., e_n; n) = P(\sum_{i=1}^{n} q_i, \sum_{i=1}^{n} e_i) q_i - C(q_i, e_i)$$

An individual firm's decision rules are characterized by the following equations:

$$q_i^c : P + P_q q_i - C_q = 0 \tag{4.8}$$

$$e_i^c : P_e q_i - C_e = 0 \tag{4.9}$$

An individual firm's private incentive to undertake abatement, $P_e = \theta\delta\gamma$, is strictly increasing in the level of consumer information, $\theta$. If consumers are uninformed about the industry's environmental performance, then $\theta = 0$ and the marginal benefit to a firm from abating pollution vanishes since price no longer varies with $e$. As a result, firms do not have any incentive to adopt pollution control methods and $e^c = 0$. If consumers have knowledge about industrial environmental performance, then $0 < \theta \leq 1$ and consumers can exercise their power to discipline an industry, providing firms with a positive price incentive to voluntarily undertake abatement efforts to reduce emission levels. Note that the incentive to voluntarily comply is also related to a firm's market power: if firms are price–takers, then the positive price effect and, hence, the incentive to voluntarily comply are absent.

Equation 4.9 also illustrates that a free–rider problem exists in the choice of abatement effort. Abatement effort or emission control input usage is a public good. No firm can be excluded from the positive benefits (outward shift in the demand curve) of an individual firm's installation decision — nonexclusivity leads to a free–rider problem. Since firms cannot be excluded from the benefits of competitors abatement efforts, their own incentive to invest in abatement technology is diminished when investment choices are uncoordinated. Individual producers do not internalize the benefits to others of their adoption level. An individual producer only takes into account the private marginal benefit of adoption, $P_e q_i$, when choosing a level of abatement rather than the social marginal benefit, $P_e Q$, which is the increase in industry marginal revenue.

Turning to equation 4.8, we can observe that an individual producer's output level also depends upon consumer knowledge about the industry's environmental performance as well as own and competitors abatement efforts and competitors output levels. The direction of the distortion in output levels will largely depend upon the relative magnitudes of the imperfect competition effect and the externality effect. Output levels will be too low if the imperfect competition effect dominates and too high if the externality effect dominates.

To determine which output effect dominates — the imperfect competition effect or the externality effect — we evaluate equation 4.2 at $Q^c$ and $E^*$. Let $P = P(Q^c, E^*)$. The imperfect competition effect dominates if and only if the following inequality holds:

$$P - (1-\theta)D_Z Z_q - C_q > 0 \tag{4.10}$$

Define the Cournot equilibrium price as $P^c = P(Q^c, E^c)$. Equation 4.10 can be rewritten as:

$$\frac{P^c - C_q}{P^c} > \frac{P^c - P - (1-\theta)D_Z Z_q}{P^c}$$

or, alternatively, as:

$$\frac{s}{|\varepsilon|} > \frac{P^c - P(\theta = 1)}{P^c} \tag{4.11}$$

where $s$ measures the market share and $\varepsilon$ measures the price elasticity of the demand curve at the Cournot–Nash equilibrium. The left–hand side of equation 4.11 measures the degree of market power at the Cournot–Nash equilibrium while the right–hand side measures the proportion of uninternalized damage in the market price. Equation 4.11 is more likely to hold when $\theta$ is large and $n$ or $\delta$ is small.

In equilibrium, since firms are symmetric, $q_i^c = q_j^c = q^c$ and $e_i^c = e_j^c = e^c$. Substituting the symmetry conditions and the assumed functional forms into equations 4.8 and 4.9 and after some algebraic manipulation we can derive the following solutions:

$$q^c = kG \tag{4.12}$$

$$e^c = \theta\delta\gamma G \tag{4.13}$$

$$z^c = \left(k - \theta\delta\gamma^2\right) G \tag{4.14}$$

where

$$G = \frac{(A-b)}{k(1+n)(1+\theta\delta) - n(\theta\delta\gamma)^2} \tag{4.15}$$

Output and pollution levels are strictly decreasing and emission control inputs are strictly increasing in $\theta$ and $\delta$. Firm (industrial) quantities are strictly decreasing (increasing) in $n$.

Comparing equations 4.5 and 4.13, it is easy to show that $e^c < e^*$, that is, abatement effort will always be underprovided relative to the social optimum. Comparing equations 4.4 and 4.12, we can show that $q^c < q^*$ whenever equation 4.11 holds.

### 4.3. Coordinated Industry Equilibrium: Industry Code

Industries have the legal option of coordinating on pollution control efforts. Although firms cannot explicitly collude on output levels without violating anti–trust laws, they can coordinate on pollution levels by cooperatively choosing abatement technologies. The irony is clear — choice of an industry code results in price collusion since the industry association effectively holds price–setting power. Accordingly, we model a coordinated industry equilibrium as a two–stage game. In the first stage of the game, an industry association chooses a level of emission control input, $e$, to maximize joint or industry profits, given individual firm output levels. In the second stage of the game, firms noncooperatively choose output levels, $q_{i,}$ taking the emission control input level as fixed at $e$. The nature of the game captures two features of the competitive environment. First, as mentioned above, while firms can legally collude on an industry voluntary code, they cannot collude on output levels, hence output levels must be chosen at the individual firm level. Second, the sequential moves of the industry association and firms introduces the ability of the industry association to commit to a voluntary code. We adopt the equilibrium concept of subgame perfection and, accordingly, solve the game backwards.

In the second stage of the game, an individual producer chooses an output level to maximize own profits, taking the voluntary code as fixed:

$$\max_{q_i} \pi_i(q_1, ..., q_n; e, n) = P(\sum_{i=1}^{n} q_i; e, n) q_i - C(q_i; e)$$

An individual firm's output decision rule is characterized by the following equation:

$$\frac{\partial \pi_i}{\partial q_i} = P + P_q q_i - C_q = 0 \tag{4.16}$$

Equation 4.16 implicitly defines an individual producer's output level as a function of competitors output levels, $q_j^J$, where $j \neq i$, and the industry voluntary code, $e$. Given firm symmetry, $q_i^J = q_j^J = q^J$, and substituting the assumed functional forms, we can write an individual producer's output rule or voluntary code response function as

$$q^J(e) = \frac{A - b + n\theta\delta\gamma e}{(n-1)(1+\theta\delta)} \tag{4.17}$$

Equation 4.17 reveals that firm level output is strictly increasing in the industry voluntary code, $e$. Once again, the positive relationship between $q$ and $e$ derives from the demand externality — installation of abatement technology shifts the demand curve outward, enhancing the incentive to produce.

In the first stage of the game, the industry association chooses an emission control input level, $e$, to maximize industry profits subject to firms' voluntary code response function $q^J(e)$. Clearly, the ability to choose and commit to a voluntary code effectively gives an industry association price–setting power. The industry association's decision problem can be written as:

$$\max_e \Pi = n\pi = n\left[P(nq^J(e), ne)q^J(e) - C(q^J(e), e)\right]$$

The industry association's decision rule is characterized by the following equation:

$$\frac{\partial \Pi}{\partial e} = \frac{\partial \pi}{\partial q^J}\frac{dq^J}{de} + \frac{\partial \pi}{\partial e} = 0 \tag{4.18}$$

Note that $\frac{\partial \pi}{\partial q^J} = \frac{\partial \pi_i}{\partial q_i} + P_q q^J(n-1)$, where $\frac{\partial \pi_i}{\partial q_i}$ is defined by equation 4.16. Applying the Envelope Theorem, equation 4.18 reduces to:

$$\frac{\partial \Pi}{\partial e} = P_q q^J(n-1)\frac{dq^J}{de} + \frac{\partial \pi}{\partial e} = 0 \tag{4.19}$$

Substituting for $\frac{\partial \pi}{\partial e}$ yields:

$$e^J : \left[ P_q \frac{(n-1)}{n} \frac{dq^J}{de} + P_e \right] Q^J - C_e = 0 \tag{4.20}$$

Two key results emerge from equation 4.20. First, an industry association can resolve the free–rider problem which characterizes uncoordinated firm choice of abatement technology. When an industry code is adopted, the industry association chooses a level of installation which maximizes the benefits to all members of the industry, that is, the increase in industry marginal revenue due to higher demand for environmentally friendly products, $P_e Q^J$. In other words, the industry association fully internalizes the benefits accruing to all members from any given level of installation. In contrast, when firms choose voluntary codes noncooperatively, they only consider the private benefits of installation. Since industry benefits of emission control input installation always exceed individual benefits, underprovision of abatement technology will be less pronounced in the case of company codes.

Second, the industry association takes into account the strategic costs associated with the indirect effect on industry output. Comparing 4.20 and 4.9, we observe that an industry association takes into account the indirect output effect on industry marginal revenue, $P_q \frac{(n-1)}{n} \frac{dq^J}{de} Q^J$; the indirect output effect is a cost associated with increasing the level of a voluntary code — an additional cost of increasing $e$ is the loss in marginal revenue due to movement down the demand curve.

Substituting the assumed functional forms into equation 4.20 and after some algebraic manipulation, we can derive the following solutions:

$$q^J = k(1+n)H \tag{4.21}$$

$$e^J = 2n\theta\delta\gamma H \tag{4.22}$$

$$z^J = \left( k(1+n) - 2n\theta\delta\gamma^2 \right) H \tag{4.23}$$

where

$$H = \frac{(A-b)}{k(1+n)^2(\alpha+\theta\delta) - 2(n\theta\delta\gamma)^2} \tag{4.24}$$

Comparing equations 4.13 and 4.22, it can be shown that an industry association will choose a higher level of emission control input usage than an uncoordinated industry, that is, $e^J > e^c$. The gap between levels of company and industry codes is increasing in $\theta$ and $\delta$, that is, when consumers are well–informed and pollution emissions are cumulative; incentives to adopt voluntary codes are strongest under these conditions and hence the free–rider problem will be most pronounced. In addition, since $\frac{dq}{de} > 0$, it follows that $q^J > q^c$. Further, it can be shown that pollution levels are lower and market prices are higher when industry codes are implemented, that is, $z^J < z^c$ and $P^J > P^c$.

Summarizing, a stable and credible industry association can resolve the free–rider problem, resulting in higher overall levels of abatement efforts which enable firms to produce higher levels of output and emit lower levels of pollution.[1] However, although firms do not explicitly collude on output choice when industry codes are adopted, output and emission control input decisions are interdependent. As a result, market power is enhanced when industry codes are adopted, resulting in higher market prices.

## 5. Simulation Analysis

Simulation of the oligopoly models of company and industry voluntary codes provide important insights into the conditions under which a voluntary compliance regime is likely to be a viable alternative to a mandatory regulatory regime for protecting the environment. The simulations focus on the roles of three critical parameters in the model: $\theta$ (consumer knowledge), $n$ (market structure), and $\delta$ (environmental damage). Numerical simulation results on quantities and welfare measures are presented in Tables A1-A3 in the Appendix. Discussion of the simulation results are presented below.

We first discuss the role of consumer information, parameterized by $\theta$. As consumers become better informed about the environmental consequences of production, firm incentives to reduce pollution levels are enhanced; as $\theta$ increases, pollution abatement is achieved by installing increasingly higher levels of emission control inputs and reducing production levels. Although emission control inputs are underprovided in both industry and company code regimes, higher levels are installed when firms coordinate; the gap between installation levels in industry and company code regimes is increasing in $\theta$ and is particularly large when the

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[1] We note that an assurance problem may exist, leading to cartel stability and commitment issues. However, analysis of such issues is beyond the scope of this paper.

free–rider problem is significant (high $\theta, \delta$ and $n$). Output levels are also higher when firms coordinate on abatement technology choices. When consumers are poorly–informed, pollution levels will be excessive, particulary in competitive industries, leading to market prices which do not reflect the full social costs of production. However, as $\theta$ increases, higher levels of emission control input usage and output levels in highly concentrated industries can lead to a reduction in pollution below the socially optimal level. This strategic manipulation of pollution levels enhances market power, leading to high mark–up pricing. Referring back to Figure 4, recall that the socially efficient price is declining in $\theta$. When $\theta = 0$, the socially efficient price equals the full social marginal cost of production. As $\theta$ increases, consumers internalize an increasingly higher level of the externality in their consumption decisions and hence, the socially efficient price is falling. When $\theta = 1$, the socially efficient price reflects only the marginal production cost. In contrast, in a market economy, price is an increasing function of $\theta$. Thus, the proportionate change in price between a voluntary regime and the social optimum is increasing in $\theta$.

Given that the adoption of pollution reduction practices is voluntary and that firms are profit–maximizers, firms will always gain as a result of the introduction of voluntary regimes. Producer surplus will also be higher when firms can coordinate and resolve the free–rider problem. We find that producer gains are highest when consumers are well–informed (as market power is increasing in $\theta$) and are particularly high in concentrated industries. Consumer surplus, on the other hand, is strictly decreasing in $\theta$ in a voluntary regime — knowledge makes consumers worse off; in contrast, consumer surplus evaluated at the socially efficient levels of output and emission control inputs in strictly increasing in $\theta$, that is, knowledge does make consumers better off in a first–best world. Declining consumer surplus is due to the strategic manipulation of prices in voluntary regimes. Consumer losses are particularly high when industry is concentrated and lowest when industry codes are implemented in competitive markets. In general, there is a transfer of surplus from consumers to producers in voluntary regimes.

The environmental consequences of voluntary regimes is also highly dependent on the level of consumer information. In general, environmental damages are declining as $\theta$ increases. However, damages will be excessive (and perhaps catastrophic) in competitive industries. Environmental damages will also be excessive in concentrated industries when consumers are poorly–informed. However, as consumer knowledge increases, strategic behaviour will result in substantially reduced emission levels and damage levels below the socially optimal level.

Welfare losses will always arise in voluntary regimes but are declining in $\theta$. Welfare losses will be substantively higher in company code regimes whenever the free–rider problem is significant. In addition, welfare losses will be high when consumers are poorly–informed about the environmental consequences of cumulative pollutants and in the case of a competitive industry emitting a noncumulative pollutant. Notably, welfare losses are relatively small when consumers are well–informed and the industry is highly concentrated.

We next discuss the role of market structure, parameterized by $n$. As the level of competitiveness in a pollution–generating industry increases, the ability of firms to exploit consumer environmental preferences declines. As a result, the capacity of a voluntary regime to control emission quantities, a fundamental concern of environmental regulators, rapidly deteriorates. Excessive emissions lead to the highest level of damages and the highest welfare losses when pollutants are cumulative and consumers are poorly–informed. Welfare losses are not significant when there is a small degree of competition in industries which emit noncumulative pollutants and in industries which adopt industry codes to limit emissions of cumulative pollutants. In general, voluntary regimes will not perform well in highly competitive industries. However, welfare losses may potentially be small for sufficiently high levels of competition.

Finally, we discuss the role of pollutant type, parameterized by $\delta$. We find that voluntary regimes result in relatively small welfare losses when consumers have strong sanctioning power (high $\theta$) and producers have strong market power (low $n$) for a wide range of pollutants. In contrast, voluntary regimes result in relatively large welfare losses whenever producers have weak market power; the exception is the case of strong consumer power and an extremely benign pollutant. Voluntary regimes also perform well in the case of noncumulative pollutants, weak consumer power and strong producer power.

The simulation results are conveniently summarized in Tables 1 and 2. Conclusions, derived from the simulation tables presented in the Appendix and Tables 1 and 2, are summarized in Tables 3 and 4.

— **INSERT TABLE 1 HERE** —

— **INSERT TABLE 2 HERE** —

Whether voluntary regimes provide efficient and cost–effective arrangements for protecting the environment depends upon the relative performances of voluntary and mandatory regimes. As discussed in Section 2 of the paper, there is considerable evidence that current regulatory structures are neither efficient nor cost–effective. Measures of welfare losses incurred under current regulatory structures are not available but anecdotal evidence suggests that losses may potentially be quite large. We adopt the rather arbitrary rule–of–thumb that if welfare losses under a voluntary regime are less than 12-15%, then voluntary regimes are potentially a viable alternative to mandatory regulation. Applying this rule–of–thumb to our simulation results we find that there are indeed conditions under which voluntary regimes should be seriously considered as a viable alternative to mandatory regulation.

**— INSERT TABLE 3 HERE —**

Referring to Table 3, we conclude that voluntarism or self–regulation should not generally be considered as a viable means of dealing with cumulative pollutants except in an environment where consumers are well–informed and an industry code can be successfully implemented in a highly concentrated industry. In this case only, the imperfect competition effect dominates the externality effect, leading to small welfare losses overall. However, it must be recognized that in such an environment, self–regulation will result in a large transfer of surplus away from consumers to producers. Consumers will experience large losses in surplus relative to the social optimum due to the anti–competitive effects of voluntary codes in this environment.

**— INSERT TABLE 4 HERE —**

Referring to Table 4, we conclude that self–regulation should be considered as a viable alternative to mandatory regulation for noncumulative pollutants except in an environment where consumers are poorly–informed and the industry is relatively competitive. When both consumers and producers are weak, voluntarism can potentially have disastrous environmental and welfare implications. Whether voluntarism may potentially dominate mandatory regulation in a competitive environment as consumers become better informed depends largely on how rapidly environmental damages escalate. If consumers are strong and producers are weak, voluntarism should be considered if and only if damages from the pollutant are rising slowly and gradually and competition is not too strong. In contrast, when producers are strong, the models analysed and simulated above predict that overall welfare losses are well–contained in voluntary regimes. Again, there are distributional and environmental consequences associated with the adoption of voluntarism. Voluntary regimes lead to a transfer of surplus away from consumers to producers. In addition, whenever there is an asymmetric distribution of power between consumers and producers, the environment loses. The environment wins only in the case of strong producers and strong consumers.

## 6. Conclusions

An analytical framework for assessing the efficiency, distributional and environmental consequences of voluntary codes is derived and presented in the paper. The analysis shows that conditions do exist under which welfare losses incurred under voluntary regimes can be relatively small. For instance, voluntary regimes may provide viable alternatives to mandatory regulation when consumers are well–informed and producers have significant market power. In addition, if pollutants are of a noncumulative nature, voluntary regimes can be a viable alternative even when there is an asymmetry in producer and consumer power.

A number of important issues emerge from the foregoing analysis. When firms have price–setting power, market incentives do exist for firms to voluntarily reduce pollution emissions in the absence of regulatory directives. Moreover, market incentives are enhanced the better informed consumers are regarding the environmental consequences of production. We find that firms will strategically exploit consumers environmental preferences to raise profits and that market power is positively related to the level of consumer informedness. Ironically, when the anti–competitive effects of voluntary codes are the strongest, overall welfare losses from voluntary regimes are the lowest. Anti–competitive effects can, however, have potentially strong distributional consequences — namely a large transfer of surplus away from consumers to producers.

A direct implication of the positive relationship between consumer knowledge and producer power is that government strategies which focus exclusively on public information provision to enhance the efficiency of voluntary regimes may have the unexpected and undesired effect of strenthening the anti–competitive effects of voluntary codes. The analysis strongly suggests that delegation of environmental regulation to the private sector should be subject to some form of government oversight. For instance, voluntary codes should be subject to vigorous scrutiny or monitoring by the government agency charged with the task of enforcing anti–trust laws since voluntary codes may have strong anti–trust implications.

The analysis also emphasizes the importance of understanding the role of market structure when deciding among alternative approaches for protecting the environment. Although the analysis presented above focusses on an oligopolistic model of industry structure, preliminary analysis of a dominant firm–competitive fringe market structure shows that voluntary regimes can potentially have less extreme distributional consequences when a firm with strong market power is subject to the pressure of a competitive fringe.[12] The presence of the competitive fringe restricts the ability of the dominant firm to exploit consumers environmental preferences and hence the exercise of market power. In particular, consumers may actually gain from a transition to voluntarism. In addition, a model with entry and exit could be examined to determine whether the adoption of voluntary codes can act as a strategic barrier to entry. Thus, further analyses of alternative market structures should be undertaken to obtain additional insights into the workings of voluntary regimes.

Although the above analysis focusses on the use of voluntary codes for controlling pollution, the framework could, with the appropriate modifications, be used to analyse the use of voluntary codes in other areas. For instance, the analysis could be fruitfully applied to the adoption of voluntary codes in the area of industrial health and safety practices as well as industrial labour practices. The framework presented above is useful for understanding the efficiency and distributional consequences of voluntary codes whenever a demand externality is present, that is, whenever consumer demand is dependent upon industrial practices. In addition, the analysis clearly shows that the success of voluntary regimes is environment or industry dependent; the outcome of voluntary regimes is highly dependent on technological, demand and environmental factors. An important advantage of the above framework is that it enables policy–makers to identify the key determining factors which must be present to ensure that adoption of voluntary codes will be a viable alternative to mandatory regulation.

## 7. Endnotes

1. While polluters will always adopt self–enforcing voluntary codes at the firm level, a free–rider induced compliance problem may arise in the case of industry voluntary codes; if firms cannot credibly commit to comply with an industry code, the industry association must provide sufficiently strong compliance incentives or an *ex–post* governance structure to prevent instability. Although enforcement issues are potentially important, we restrict attention to an analysis of the *incentives* to adopt voluntary codes at both the firm and industry level.

2. In general, the environment has some assimilative capacity for breaking down noncumulative pollutants while cumulative pollutants, as the name suggests, cumulate in the environment. As a result, environmental damages tend to escalate much more rapidly for cumulative as opposed to noncumulative pollutants.

3. I broadly classify the Pigovian school of thought to include the literature on mandatory regulatory regimes. See Pigou (1920) and Coase (1960).

4. Under a command–and–control regime, the public holds the right to a socially acceptable level of pollution. Polluters may freely pollute up to the socially acceptable level of pollution but must pay for the right to pollute beyond that point in the form of penalties for noncompliance. In contrast, the public holds the right to a clean environment under an incentive–based regime and polluters must pay for the right to pollute any level of pollution.

5. Under Pigovian solutions, the extent to which pollution control costs are passed on to consumers in the form of higher prices depends upon the elasticity of the demand curve.

6. See Farrell (1988) and Maskin (1994).

7. The levying of financial penalties requires that the regulatory agency undertake two costly activities — monitoring and sanctioning activities. Monitoring entails site visits to obtain measurements of emission or concentration levels and testing to determine whether or not the firm is in compliance with the law. If a firm is found to be out of compliance, then regulators often have a range of sanctioning options available, ranging from administrative

hassling or fines to criminal prosecution. For a detailed analysis of regulatory choice of monitoring and sanctioning activities see Garvie and Keeler (1994).

8. See generally Braden and Kolstad (1991).

9. An alternative interpretation of $\theta$ is that $\theta$ represents the weight that a fully–informed consumer places on the environmental consequences of production.

10. See Garvie (1998) for a more general analytical treatment.

11. The *Second Law of Thermodynamics* states that entropy increases. In other words, it is physically impossible to eliminate all waste, hence $z > 0$ for all $q > 0$.

12. See Garvie (1998).

## 8. References

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## 9. Appendix

Simulation results for different values of $\theta$, $\delta$, and $n$ are presented in the Tables below. Each Table provides data on proportionate changes in market price ($P$) and industry quantity variables (output, $Q$, emission control input usage, $E$, and pollution discharges, $Z$) which emerge under company codes (labelled $c$) and industry codes (labelled $J$) relative to the socially optimal variables. In addition, proportionate changes in consumer surplus ($CS$), environmental damages ($D$) and social welfare ($W$) relative to the social optimum are also reported for the two regimes to facilitate analysis of the distributional and efficiency consequences of voluntary codes. We do not report proportionate changes in producer surplus since profit–maximization always results in higher firm profits in voluntary regimes and strictly higher profits in coordinated voluntary regimes.

Table A1 reports the simulation results regarding the role of consumer information, $\theta$. Results are reported for four different environments: (i) cumulative pollutant emitted by highly concentrated industry ($\delta = 4$, $n = 2$), (ii) cumulative pollutant emitted by highly competitive industry ($\delta = 4$, $n = 250$), (iii) noncumulative pollutant emitted by highly concentrated industry ($\delta = .5$, $n = 2$), and (iv) noncumulative pollutant emitted by highly competitive industry ($\delta = .5$, $n = 250$).

**— INSERT TABLE A1 HERE —**

Table A2 reports the simulation results regarding the role of market structure, $n$. Simulation results are reported for four different environments: (i) consumers poorly about cumulative pollutant ($\theta = .2, \delta = 4$), (ii) consumers well–informed about cumulative pollutant ($\theta = .8, \delta = 4$), (iii) consumers poorly–informed about noncumulative pollutant ($\theta = .2, \delta = .5$), and (iv) consumers well–informed about noncumulative pollutant ($\theta = .8, \delta = .5$).

**— INSERT TABLE A2 HERE —**

Table A3 reports the simulation results regarding the role of pollutant type, $\delta$. Simulation results are reported for four different environments: (i) poorly–informed consumers, highly concentrated industry ($\theta = .2$, $n = 2$), (ii) well–informed consumers, highly concentrated industry ($\theta = .8$, $n = 2$), (iii) poorly–informed consumers, highly competitive industry ($\theta = .2$, $n = 250$), and (iv) well–informed consumers, highly competitive industry ($\theta = .8$, $n = 250$).

**— INSERT TABLE A3 HERE —**